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Final Report

on

**Studies of Ocean Volume Reverberation at High
Acoustic Frequencies**

Submitted to

**Commander
Office of Naval Research
801 North Quincy Street
Arlington, VA 22217-5000**

Attention: B. Zahuranec, Code 1123B

Prepared by

**D.V. Holliday
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October 8, 1991

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Tracor Applied Sciences

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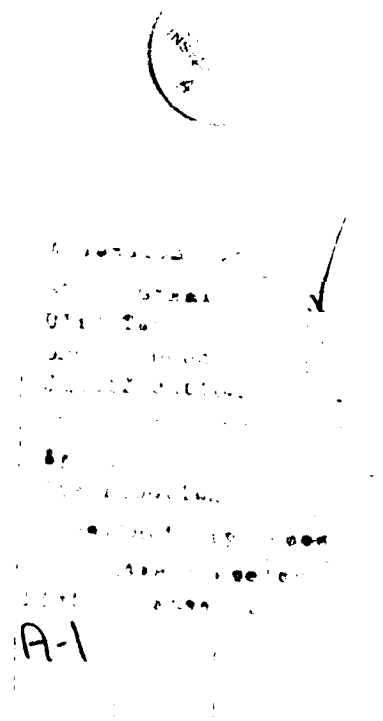
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Studies of Ocean Volume Reverberation at High Acoustic Frequencies

Executive Summary

This research program was conducted with the joint sponsorship of the Office of Naval Research, Ocean Sciences Directorate (Ocean Biology and Ocean Acoustics Programs) and the National Science Foundation, Ocean Sciences Division (Biological Oceanography and Oceanographic Technology Programs). The research has been a joint effort involving Tracor Applied Sciences, Analysis and Applied Research Division and the University of Southern California, Hancock Institute for Marine Studies. The co-principal investigators were D.V. Holliday (Tracor) and R.E. Pieper (USC). C.F. Greenlaw (Tracor) and J.K. Dawson (USC), J. Costello (USC) and J. A. Dmohowski (USC) also contributed substantially during the course of the research program. G.S. Kleppel, originally at USC, now at Nova University, was funded through the USC grant from NSF as a participant in several elements of this research. Other investigators who were involved in some phase of the research as cooperating PI's, but with independent funding, were M. Reeve (U. of Miami), P. Ortner (NOAA/AOML), D. Frazel (Nova U.), J. Napp (U. of Miami), K. Brander (MAFF Lowestoft, England) and R. Mitson (MAFF Lowestoft, England).

The principal thrust of this research was to improve the ability of oceanographers to quantitatively measure small-to-intermediate scale spatial and temporal distributions of marine zooplankton, with size discrimination, in relation to the distribution of physical and chemical features in the ocean environment. The research resulted in the development of a new technology based on the scattering of high frequency underwater sound at multiple frequencies from zooplankton and micronekton. The technology allows one to examine distributions of small zooplankton, by size, in relation to ocean physics and chemistry, *in situ* and essentially in real time.

The most sophisticated implementation of this technology is the Multi-frequency Acoustic Profiling System (MAPS). During the course of this work, it was used as a tool in numerous research programs that were focused on different aspects of the ecology of marine zooplankton. This new tool was used in support of science programs in a wide range of ocean environments. These include the

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California Current (off southern California), the Coastal Transition Zone (off northern California), the Gulf Stream core, a frontal zone near Cape Hatteras, a frontal zone near Cape Canaveral, the slope water of the North Atlantic (north of a meander in the Gulf Stream) and at several locations in the Irish Sea.

I. Introduction

The early part of this research focused on the development of a new technology to detect and study small-to-intermediate scale distributions of zooplanktonic organisms. Initial efforts were focused on achieving an understanding of the processes involved in the scattering of high frequency (100 KHz to 10 Mhz) underwater sound from small zooplankton and micronekton (125 microns to 20 cm in length). An acoustic method for determining the spatial and temporal distribution of small zooplankton, with size discrimination, was successfully developed and validated. Several increasingly complex and more capable generations of instrumentation were developed.

The most capable of these instruments is the Multi-frequency Acoustic Profiling System (MAPS). The MAPS was successfully used to estimate the numerical abundance and biovolume of small zooplankton with a vertical spatial resolution of meters and a horizontal spatial resolution of 100's of meters. The MAPS also includes a variety of ancillary (non-acoustic) sensors of water column properties. These sensors, which include depth, temperature, salinity, fluorescence and light, are used to describe physical and chemical environment in which the zooplankton live. Distributions and dynamics of zooplankton biomass, by size, were studied in relation to the concurrent distributions and dynamics of phytoplankton (chlorophyll fluorescence), temperature, salinity and light.

II. Summary of Results

Zooplankton distributions vary at relative small spatial and temporal scales. Our objectives were to develop methods to rapidly describe and quantify the relationship between zooplankton and their environment in a variety of oceanic areas. The Multi-frequency

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Acoustic Profiling System (MAPS) was used to estimate the abundance and biomass of zooplankton and micronekton in 40 size classes (21 independent) from 0.125 to 20 mm in length. The near real time capability of the MAPS allowed us to carry out precise, directed sampling with nets and pumps for taxonomic identification and for detailed studies such as egg production studies and HPLC analyses of gut contents.

The MAPS has revealed detail in zooplankton spatial structure that had not previously been observed and cannot be observed by conventional sampling techniques. Coherences were observed between zooplankton distributions, physical properties of the water column and phytoplankton distributions over vertical scales from tens of meters or greater. Horizontal coherences of zooplankton biomass with the same parameters were observed from scales of tens of kilometers down to hundreds of meters. Data collected along transects (sections) across oceanographic features or over defined areas have emphasized the importance of physical or oceanographic features (e.g., fronts, the shelf-slope break, internal waves, filaments, tidal mixing and stratification) in defining zooplankton distributions.

Zooplankton size - abundance spectra were similar for study areas off southern California and in the Gulf Stream. The size distributions differed in the oceanographically more complex areas off central California and in the Irish Sea. Associations of zooplankton peaks with the chlorophyll maximum occurred only off of southern California and did not seem to be related to zooplankton feeding. Spatially, distributions were generally bounded and controlled by physical features; processes such as growth, feeding and migrations appeared to occur within limits set by the physical system. Short-term temporal coherence was more difficult to assess.

III. Publications and Presentations

In addition to the annual progress summaries provided for each year's ONR Program Summaries (not individually listed) and several special progress reports (e.g., "Studies of Ocean Volume Reverberation at High Acoustic Frequencies", T-84-06-007-U, D. V. Holliday and R. E. Pieper, 34 pp - April 16, 1984 and "Progress Report for 1986 - Studies of Ocean Volume Reverberation at High Acoustic Frequencies", T-87-06-7001-U, D. V. Holliday and R. E.

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Pieper, 13 pp., etc.), the following publications and presentations were supported either wholly or in part by ONR and NSF funding provided under this contract.

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